NOTES ON THE MISSISSIPPIAN CHERT OF THE ST. LOUIS AREA

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The origin of chert is a question which is still open to discussion. Although several of the chert series of Europe have been studied somewhat in detail by a number of geologists,[1] among the more important Hull and Hardman, Hinde, Sollas, Renard, and Cayeux, the conclusions reached with regard to the origin of chert have been considerably at variance. In this country Lawson and Palache seem to have demonstrated the organic (radiolarian) origin of certain Californian cherts. The Missouri cherts, chiefly Mississippian, and some of the closely associated cherts of neighboring states have been studied, although not in detail, by Shepard, Ball and Smith, and Van Tuyl, and, in thin section only, by Hovey. The conclusions as to the origin of the chert have not been in agreement. The present paper presents the results of a detailed study of the Mississippian cherts of the St. Louis area both in the field and in thin sections.

OCCURRENCE OF THE MISSISSIPPIAN CHERT OF THE ST. LOUIS AREA

The Mississippian chert of the St. Louis area is found in the St. Louis and in the Burlington-Keokuk limestones, to a slight extent in the Warsaw shales, and in very rare, small patches in the

[1] E. Hull and E. T. Hardman, *Trans. Royal Soc., Dublin*, I (1878), 71. G. J. Hinde, *Geol. Mag.* (III), IV (1887), 435–46. W. J. Sollas, *Am. Mag. Nat. Hist.* (5), VI (1880); VII (1881); *Proc. Roy. Soc., Dublin*, VI (1887), Part 11. A. F. Renard, *Bull. Acad. Roy. Belgique* (2), XLVI (1878), 471. L. Cayeux, *Ass. franç. pour l'avanc. de Sci.* (Carthage, 1906), pp. 220–93. A. C. Lawson and C. Palache, *Bull. Geol. Dept. U. of Cal.*, II (1902), 354–65. E. M. Shepard, *U.S. Geol. Surv., W.S. Paper 195* (1907), p. 19. T. M. Van Tuyl, *Proc. Iowa Acad. of Sci.*, XIX (1912), 173–74. E. O. Hovey, *Mo. Geol. Surv.*, VII, Part II (1894), pp. 727–39.

Salem limestone. The stratigraphic position of the chert beds is shown in the accompanying generalized section of the St. Louis area (Fig. 1). The Burlington-Keokuk limestone wherever exposed

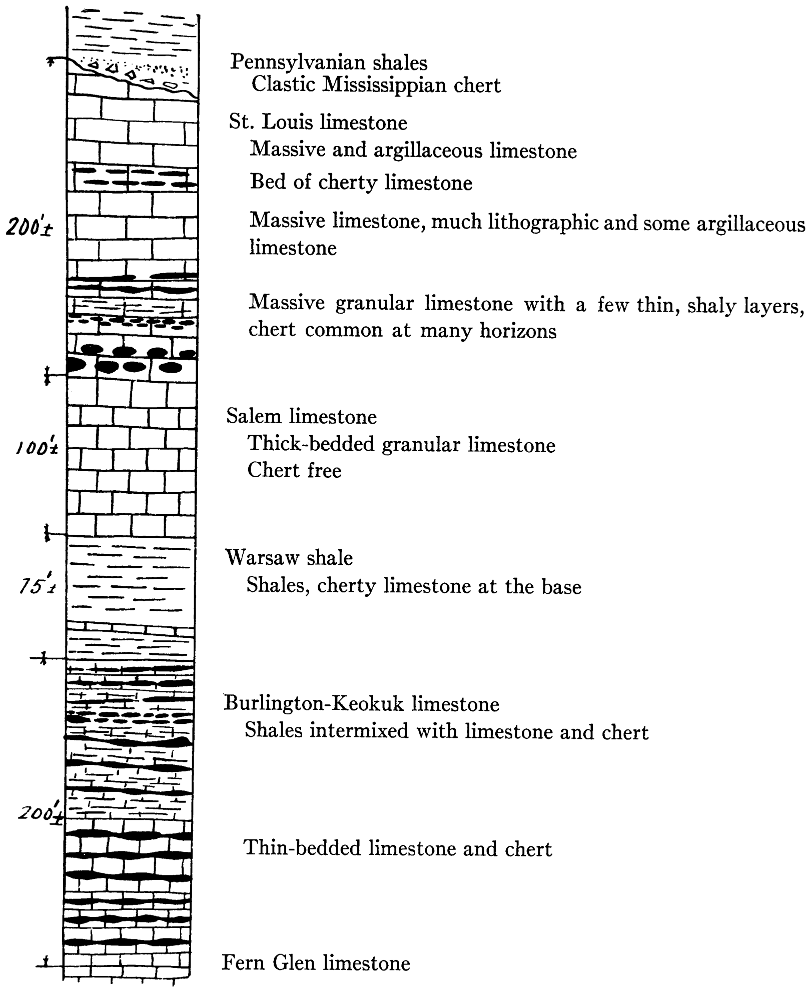

FIG. 1.—Generalized section of the St. Louis region

in this area is consistently very cherty. The amount of chert in the St. Louis limestone varies considerably from place to place. The presence of more or less chert at the base is characteristic, but it

was impossible to correlate with certainty throughout the area the higher cherty horizons.

MORPHOLOGY OF THE CHERT BEDS

The general form of the chert varies considerably from bed to bed, although it seems to be more or less constant for any individual horizon. It is possible to distinguish several distinct types of occurrence of the chert. Most of the chert in the Burlington-Keokuk limestone and some of the chert in the St. Louis limestone are in nodular bands or bands of flattened nodules. The nodules are irregularly elliptical with horizontal diameters subequal and one and a half to twice the vertical diameter, and are seldom less than three centimeters or more than ten centimeters in diameter vertically. The nodules are rounded and usually sharply delimited, at least to megascopic examination, from the inclosing limestone. In any given chert bed these nodules show distinct distribution parallel to the stratification and by coalescence form the nodular bands intercalated between the thin limestone beds. In a few chert beds in the Burlington-Keokuk the chert is irregularly ramifying, with angular outlines, and in general pattern resembles some of the mottled Ordovician limestones. Although the chert of this type usually crosses many distinct layers of the limestone, the greatest development shows distinct distribution parallel to the stratification. A form of the chert very characteristic of the St. Louis limestone and found but very rarely in the Burlington-Keokuk are the bands of nodules, spherical or ovoid in shape and six to sixty centimeters in diameter. The contact of the nodule and the limestone is apparently sharp, but there is usually present a thin chalky-looking transition zone. The nodules in a given band characteristically are well aligned to some horizon, in many cases the middle of a thick limestone bed. A form of the chert that is found both in the St. Louis limestone and in the Burlington-Keokuk limestone is a thin band, pancake-like in the St. Louis and platelike in the Burlington-Keokuk. These bands most commonly are six to ten centimeters thick, but in some cases much more, and fifteen to fifty meters long. The contact of the chert of these bands with the limestone seems to be sharp.

LITHOLOGICAL CHARACTER OF THE CHERT

To the naked eye the chert characteristically appears stony, but in some cases granular or chalky, although in the latter cases the chert is not appreciably less tough or hard. In color the chert varies from dirty white to dark gray and, except for one thin band of chalcedonic chert, is mottled and banded. The mottling is similar in effect to that given by the grain to the limestone and is apparently a pseudomorphic character of the chert reflecting the granular character of the limestone. The banding is concentric with the form of the nodule, or horizontal. In the latter case it is a retention of the stratification markings. The chert with rare exceptions is fossiliferous wherever the limestone of that horizon is fossiliferous. Crinoid stems are by far the most common fossil. Bryozoa, Spiriferi, Producti, and other brachiopods, Lithostrotion in the St. Louis limestone and Fusulina are also common. A notable feature about the fossils is that in a very great number of cases they are still calcareous and do not show the effects of the siliceous replacements of the rest of the rock.

In thin section under the microscope the chert is seen to be composed chiefly of quartz with more or less calcite, and in some cases with chalcedony, opal, dolomite, pyrite, and iron staining. The quartz making up the mass of the chert is in excessively fine grains, less than 0.01 mm. in diameter, which are not clearly distinguished even under the high power, and it is to the compensation due to the superposition of these small grains that many of the areas dark under crossed nicols are to be attributed. Locally, in many cases within a shell, there are patches of allotromorphic grains of larger size (0.1 mm.). In a few thin sections there were seen larger, subangular, clastic grains. The calcite, abundant through much of the chert, is in small rounded grains that cloud certain areas or form patchy aggregates through the chert, or is in large grains forming the unreplaced shells. The calcedony, when present, is in thin, fibrous, wavy bands that permeate part of the chert, lining shells, and microscopic cavities. The presence of the opal is inferred from the presence in part of the chert of much isotropic material with a moderately low index of refraction. The dolomite, where observed, was in small rhombs scattered through the chert and was distinctly

more abundant in the chert than in the surrounding limestone. Pyrite was present in only a few cases and was in small cubes in the center of quartz-filled cavities. In much of the chert there is a slight amount of iron staining present.

The structure of the chert as revealed under the microscope varies considerably. Part of the chert is massively composed of very fine grains, whose boundaries cannot be made out. Much of the chert is similarly composed in large part, with ramifying, banded microscopic masses of calcedonic material or interlocking quartz grains, which seemed to have filled pre-existing cavities. The interior cavities of shells are in most cases filled with interlocking quartz grains. The shells, even very minute ones, for the most part are composed of calcite in medium-sized grains, but in some cases show partial or complete replacement. Where replacement of a shell has taken place it is mostly by fine allotriomorphic quartz granules. Concentric banding is shown by much of the chert and is caused in some cases by very slight differences in the amount of staining, probably ferruginous, and in other cases by a variation in the amount of admixed calcite grains, the calcite rich areas tending to a chalky white color. In a chert much resembling in marking the mottled Ordovician limestones the mottling is likewise due to a rapid variation of the proportions of calcite to quartz grains. Banding due to stratification is present in some of the chert and is shown by the orientation of minute shells, by variation in the amounts of a cloud of fine black specks, and by variation in the staining.

RELATION OF CHERT TO SURROUNDING LIMESTONE

The character of the contact of the chert and the limestone apparently varies with the different chert beds. In many cases there is a visible transition extending over a zone of one to two centimeters. This is particularly the case with the spherical nodules of the St. Louis (Fig. 2). But the contact more commonly is sharp, at least under megascopic examination. In the Osage chert of Iowa such contacts are reported by Van Tuyl microscopically to show gradual transition. In the thin sections of St. Louis

chert examined the transition was distinctly sharp, being confined to a zone of 0.2 to 0.4 millemeters in width.

The lateral contacts of the larger, semispherical nodules can be seen in many cases to be zones of slight displacement. The lines of stratification running into or across the chert are broken and slightly displaced upward, the more so toward the top of the nodule, and not at all or only faintly in reverse at the base. The ends of the line of stratification in the adjoining limestone in many cases

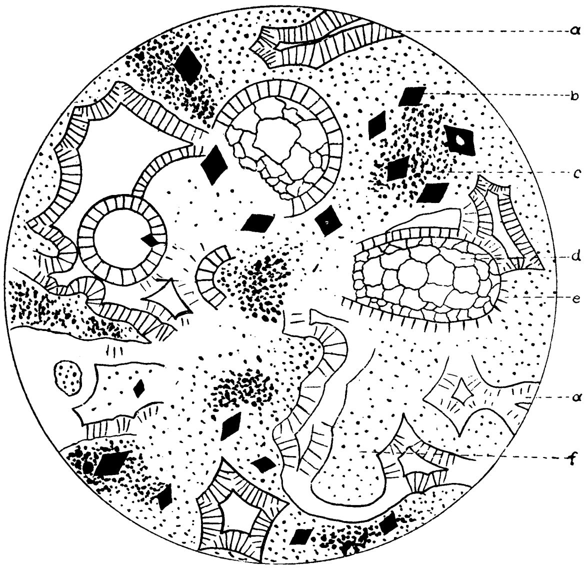

FIG. 2.—Chert from the St. Louis limestone, St. Louis, Missouri, under the high power: *a*, chalcedony; *b*, dolomite rhombs; *c*, limonite stain; *d*, granular quartz; *e*, silicified shell; *f*, microgranular groundmass.

are bent up near the nodule with the upper ones arching over, but in other cases run to the contact without deviation. Slickensides were found in a very few cases on the lateral contacts, showing relative movement upward of the chert of the nodule.

CHARACTER OF THE ROCK INCLOSING THE CHERT

Although chert is confined to calcareous rocks, the exact character of the rock in which chert appears varies widely. The grain seems to have no effect on the presence of chert, which is found

indifferently in fine-grained, even lithographic limestones, and in coarse-grained ones. It is found in massively bedded as well as in thin-bedded limestones. It is not found, to the writer's knowledge, in pure or only slightly calcareous sandstones or shales, but is found in arenaceous and argillaceous limestones. It is found in highly magnesium limestones and in very pure limestones. A series of analyses of the chert-bearing St. Louis and Burlington-Keokuk limestones at St. Louis show a variation in composition as given in Table I.

TABLE I*

Limestone	Insoluble Siliceous Residue	Combined Oxides	$CaCO_3$	$MgCO_3$
St. Louis.............	1.48–9.56	0.35–1.82	61.88–94.97	0.94–24.53
Burlington-Keokuk....	1.10–4.35	0.40–1.82	77.95–94.50	3.18–14.84

*Analyses by A. E. Atwood, *Geol. Surv. of Missouri, Bull. No. 3* (1890), p. 77.

CONTEMPORANEOUS CHERT OF OTHER AREAS

In areal distribution these Mississippian cherts are not restricted to the St. Louis area, but are widespread and are characteristic of the St. Louis limestone and equivalent formations and the Burlington-Keokuk limestone and equivalent formations practically wherever they are found. The Salem limestone of the St. Louis area is free from chert, as is also the Bedford oölite, its equivalent to the east. The exact extent of the distribution of the chert in the St. Louis limestone and the Burlington-Keokuk limestone is best shown graphically in Figs. 3 and 4, on which are plotted the outcrops of these formations and the areas in which they are chert-bearing. The correlation of formations on these maps is taken largely from B. Willis' "Index to the Stratigraphy of North America," *U.S. Geol. Surv. Prof. Paper 71*. While the morphology of these equivalent chert beds varies somewhat from locality to locality, yet there seems to be a greater or smaller constancy of habits of the chert of each formation. The St. Louis is characterized by even, ball-like chert even to Alabama, while the Lauderdale is spoken of as platelike, and the Boone chert and Grand Falls chert of western Missouri are said to be lenslike or sheetlike. It is perhaps worthy

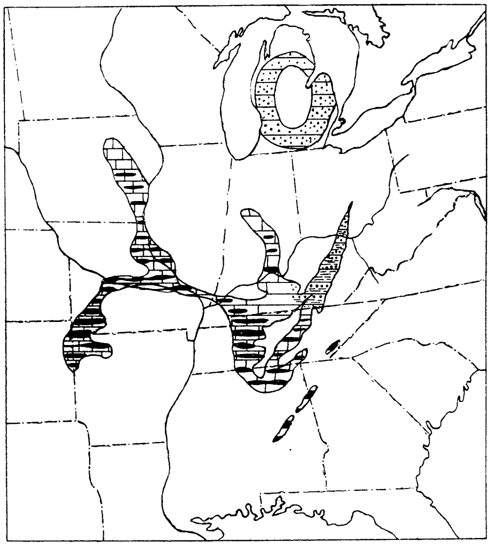

FIG. 3.—Distribution of the chert in the Burlington-Keokuk limestone and equivalent formations.

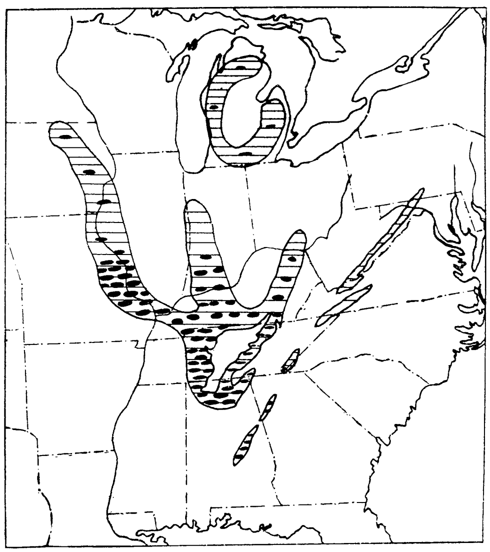

FIG. 4.—Distribution of the chert in the St. Louis limestone and equivalent formations.

of note, although very possibly nothing more than a coincidence, that much chert is found in the lower Carboniferous limestones of England, Ireland, and Belgium.

AGE OF CHERT

In age the chert of the Mississippian of the St. Louis seems without doubt to lie between the early Pennsylvanian and the time of formation of the chert-bearing limestones. The evidence of the pre-Pennsylvanian age of the chert lies in the presence of the Mississippian chert as clastic fragments in the base of the Pennsylvanian. In a Missouri-Pacific railroad cut between Kirkwood and Barrett's Station, St. Louis County, Missouri, and also in a Frisco railroad cut a half-mile east of Meramec Highlands, clastic chert carrying Lithostrotion proliferens and Spirifer Keokuk and showing predepositional weathering is to be found in abundance at the base of the Pennsylvanian shales. In Miller County, Missouri, clastic chert from the Burlington limestone is reported as being present in the Graydon sandstones and the Coal Measures shales. In the Joplin district likewise clastic Burlington chert is reported as lying at the base of the Pennsylvanian.

The evidences of the formation of the chert later than the formation of the containing limestone are several. The replacement of fossils has been cited and probably in some cases correctly so. Although the fossils in the great number of cases have not been replaced, the replacement of the fossils, especially the larger ones, when studied in their sections under a microscope seems, partly at least, surely to have taken place after the formation of the chert. The retention in the chert of the markings of the limestone, including the grain, stratification, styolithes, and fossiliferous character, is valid evidence of the secondary character of the chert. The mottling of the chert in very many cases accurately reproduces the appearance of the granular character of the limestone. The stratification markings and the variation in grain and fossil content in the different layers can in many cases be traced into or across the chert. The arching of the stratification and the faulting and slickensiding at the contacts of the nodules are also evidences of the secondary character of the chert. The stratification of the limestone in which

the pancake-like chert bands appear, for example, is more or less contorted, although in the closely associated, chert-free beds it is even and regular. The slight vertical displacement in the slickensides that are found at the lateral contacts of some of the larger nodules has already been mentioned.

Yet while the chert seems definitely to be secondary, there is an aspect on its part of contemporaneity with the limestone. This is evidenced by the widespread development of the chert in the St. Louis limestone and in the Burlington-Keokuk limestone, although the intervening Salem limestone—Bedford oölite limestone—is practically chert-free. The constancy of habit of the chert in the St. Louis limestone and in the Burlington-Keokuk, respectively, over a wide area has already been noted. The development of the chert also is parallel to the stratification. In a band of isolated nodules there is characteristically a striking alignment of the nodules at some level in a bed, often a massive one. There are in some cases several bands, and in a few cases there is no alignment of the nodules, but where the bands are present they are parallel to the stratification. The nodule-containing bed is in some cases three or four feet thick, with no shale partings, is uniform in grain and character throughout, and shows no apparent cause for percolating waters, whether silica-bearing or not, to flow at certain definite and localized levels. The pancake-like chert masses and the chert lenses likewise show conformity to stratification, although in this latter case there is in many places coalescence of several lenses by lateral thickening. As far as could be seen there was no possibility of localization of the chert at definite levels by control of percolating waters by shale partings or such. If the chert were purely epigenetic, it would seem probable that the chert bands would show some tendency to cut across the stratification.

The various theories that have been proposed to explain the origin of chert may be said in essence to be six.

I. The silica is of organic origin, derived chiefly from the spicules of siliceous sponges. The silica may be derived from other of the siliceous organisms, as, for instance, in the case of the radiolarian cherts of California.

1. The chert is supposed to be derived from colloidal silica which formed from the decomposition of siliceous sponges and collected in the depressions of the sea floor. The chert bands are supposed to represent former sponge beds, where the sponge remained accumulated in place over a considerable area.

2. The chert is supposed to form before consolidation of the limestone through the solution of scattered siliceous spicules and the almost immediate replacement of parts of the limestone.

3. The chert is supposed to form after the consolidation of the limestone through the solution by percolating waters of the siliceous spicules and the replacement of part of the limestone by this dissolved silica.

II. The silica is supposed to be of inorganic origin.

4. The chert is supposed to form by the precipitation of silica and the replacement of the limestone in the presence of circulating waters which have passed through sandstones, arenaceous rocks, or rocks containing silicates.

5. The chert is supposed to result from the reaction of the dissolved silica of sea-water with the limestones, with the consequent precipitation of the silica and with possibly a later concentration.

6. The chert results from the diffusion of silica in solution through a limestone. The concentration will vary in the direction of the diffusion, and the deposition resulting when the concentration is sufficient will be in zones perpendicular to the direction of diffusion. As the conditions for diffusion are more favorable in the early days of the consolidation and as the most likely direction for the diffusion is upward toward the surface or downward from it, the deposition will be parallel to the stratification, although independent of it. The development of the chert in successive zones is due to the lowering of the concentration immediately around the first started zone or zones of crystalizing material. The silica may be derived from organic or inorganic sources.

ORIGIN OF THE CHERT OF THE ST. LOUIS AREA

The source of the silica of the chert of the St. Louis area is not as clear as in the cases of the English cherts and flints, the radiolarian cherts of California, and the cretaceous cherts of Texas, and

apparently must remain a matter of conjecture. Evidence of an organic origin is wanting. In slides of the St. Louis chert spicules were present only in one case. In his study of slides of the Missouri cherts Hovey reports that he found only one carrying sponge spicules. Likewise Van Tuyl in his study of the cherts of the Osage series found sponge spicules present in only one sample. Of the presence in numbers in the Mississippian seas of other silica-secreting organisms nothing is known.

In the case of the cherts of the St. Louis area the theory that the chert is formed from the collection of colloidal silica on the sea floor is not applicable, since the chert is plainly secondary. Hinde's application of this theory to explain the presence of unsilicified shells in the chert is not necessary, as the differential replacement is readily accounted for by the lower solubility of the shell material. In this connection a brief series of tests was run on the relative solubility of recent and fossil pelecypod shells, fossil brachiopod shells, on crinoid stems, and on chert-bearing and chert-free limestone. The material was powdered to pass through a two-hundred-mesh sieve and was digested in 25 cubic centimeters one-half normal HCl, plus 350 cubic centimeters distilled water, and the time required for neutralization, as shown by methol orange, was noted. A marked tendency was shown toward less solubility on the part of the shells, crinoidal limestone, and chert-free limestones, such as the Salem, and greater solubility on the part of the limestones associated with chert. The experiments were not extended enough to be conclusive.

That the chert was formed before the consolidation of the limestone from silica derived from the solution of siliceous spicules or tests is possible in the case of some of the chert. But it is definitely not possible in the case of most of the chert, as the chert did not form until after the limestone had acquired its granular character. The formation of the chert in a similar manner during, or later than, the consolidation is more possible. The chert is secondary and is pre-Pennsylvanian, and therefore must have formed during, or not long after, the consolidation of the limestone. There is, however, no positive evidence of the organic origin of the silica. The suggestion that the silica of the chert is exotic and that it has

been introduced from other siliceous formations by the underground circulation, possibly that of the geologic present, does not seem valid. The formation of the chert cannot have taken place through the agency of the present-day circulation, since the presence of the chert at the base of the Pennsylvanian shows the period of formation to have been late Mississippian or early Pennsylvanian. The jasperoid of the Joplin district, furthermore, is a chertlike siliceous deposit that is said to have been deposited by the same underground circulation that is responsible for the mineralization of the region. But the jasperoid is later than the chert and distinctly different. The more serious objection, however, is the conformity of the chert with the stratification. Vertical zones following the joints are not found. The chert is found widespread, but is not found in an adjacent formation and is more or less similar over wide areas, but different in aspect in the different formations.

The derivation of the silica of the chert through precipitation from sea-water is a possibility. Silica is precipitated from solution by calcite and replaces it when H_2CO_3 is present, and, as the accumulating sediments of the ocean bottom usually contain decaying organic matter, H_2CO_3 should be present. A tenth of the yearly increment of saline material in the ocean is silica, but the silica content of sea-water is practically nil, 1 part in 220 to 460 thousand. The very considerable annual increment of silica must therefore be removed quickly, either by direct chemical precipitation or through the action of organic agents. In the case of the Mississippian beds of the St. Louis area it is not known that siliceous organisms were present to any important extent at the place and time of the deposition of the beds. The degree of concentration of the silica in the ocean-water, in connection with the slow rate of diffusion and proximity or distance from the mouth of a river, may be an important factor, contributing to the lack of chert in some limestones, as, for instance, the Salem and Kemmswick limestones. Such chert-free limestones may have formed at a distance from the mouths of rivers, and the silica may have been completely precipitated before currents brought these waters to the place of deposition of these beds.

The principles of diffusion as given by Liebesang and Cole in connection with the origin of flint partially explain some of the features of the chert of the St. Louis area. These principles seemingly explain the formation of the chert after, but not long after, the formation of the limestone—the position of the chert parallel to the stratification but independent of it, the rhythmic deposition of the chert, and the excessive development of the chert within a few hundred feet of a great uncomformity. They are equally applicable whether the silica is derived from organic or inorganic sources, and would seem to necessitate a rather general distribution at the start of siliceous material through the mass. The particular localization at a given horizon of a chert bed might be affected, however, through the influence of a local excess of siliceous material on the concentration at that horizon. The localization might also be affected by the solubility of the limestone of the various horizons. A serious difficulty that would seem to arise in connection with the application of these principles in the present case is the presence of the numerous argillaceous beds. It is difficult to see how much diffusion could take place through these shale beds, and the diffusion would seem necessarily to be confined chiefly to lateral diffusion through the more porous beds.